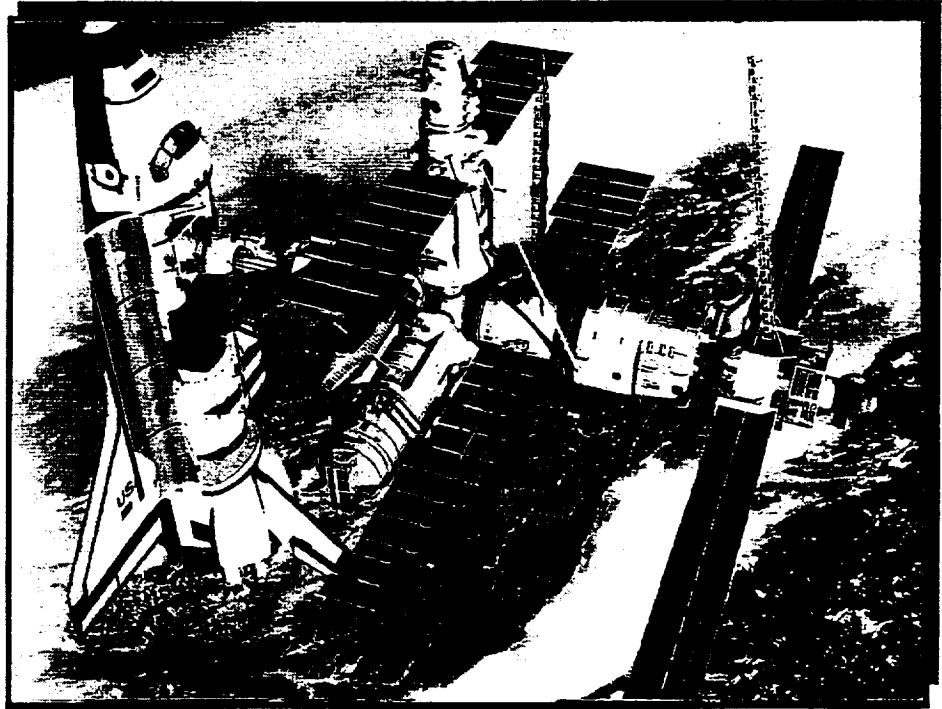




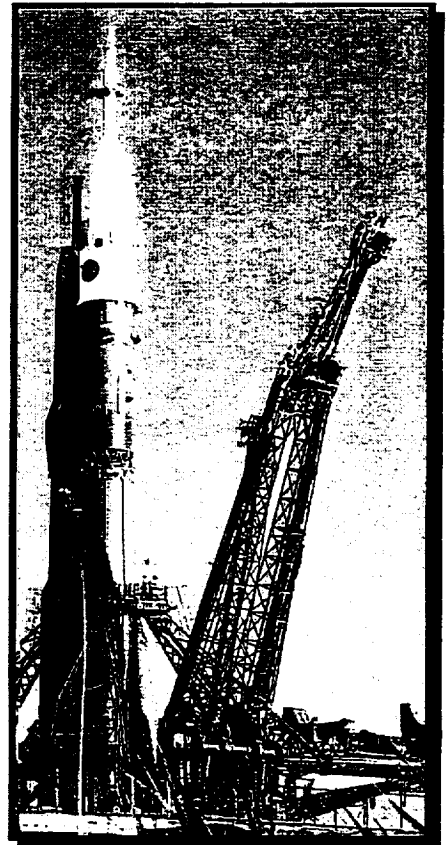
**Fourth Report
of the
Task
Force
on
the**



Shuttle-Mir Rendezvous & Docking Missions

March 1, 1995

**A Task Force of the
NASA Advisory Council**



THOMAS P. STAFFORD
1006 Cameron Street
Alexandria, VA 22314

March 1, 1995

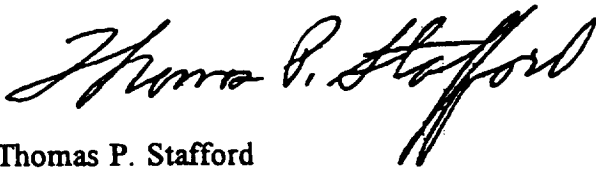
Dr. Bradford Parkinson
Chairman, National Aeronautics and
Space Administration Advisory Council
National Aeronautics and Space Administration
Washington, DC 20546-0001

Dear Dr. Parkinson:

Enclosed is the fourth report of the NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions. This report is the culmination of a two and one-half month review of preparations in Russia for the Phase 1A missions (Soyuz TM-21, Mir 18 Main Expedition, and STS-71). Once again the Task Force received tremendous support from many individuals and organizations at NASA. The same applied to our site visits in Russia where we were met with an openness and candor which served to reinforce our confidence in the ultimate success of the upcoming missions.

Over the next two months, the Task Force will be focusing its efforts in two areas. The first are the preparations for STS-71, including the status of the Orbiter Docking System and the analysis of data produced by the STS-63 mission. The second area is the NASA and NASA contractor presence in Russia, including the interaction of Phase 1 and Phase 2 personnel, NASA and contractor functions, and the transition from Phase 1 to Phase 2.

Sincerely,



Thomas P. Stafford

cc:
NASA/HQ/Code A/Mr. Goldin
NASA/HQ/Code A/Gen. Dailey
NASA/HQ/Code A/Mr. Mott
NASA/HQ/Code M/Dr. Littles
NASA/HQ/Code M/Mr. Wisniewski
NASA/HQ/Code M/Mr. O'Connor
NASA/HQ/Code M/Mr. Trafton
NASA/HQ/Code M/Mr. Vantine
NASA/HQ/Code Z/Ms. Accola
NASA/HQ/Code A/Dr. Huntoon
NASA/JSC/Code YA/Mr. Holloway

FOURTH REPORT

OF THE

NASA ADVISORY COUNCIL
TASK FORCE ON THE SHUTTLE-MIR
RENDEZVOUS AND DOCKING
MISSIONS

March 1, 1995

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1 EXECUTIVE SUMMARY

1.1 Charter

On December 6, 1994, the NASA Administrator, Mr. Daniel Goldin, requested that Lt. Gen. Thomas P. Stafford, in his role as the chairman of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions, lead a team composed of several Task Force members and technical advisors¹ to Russia with the goal of reviewing preparations and readiness for the upcoming International Space Station Phase 1 missions. In his directions to Gen. Stafford, Mr. Goldin requested that the review team focus its initial efforts on safety of flight issues for the following Phase 1A missions²:

- The Soyuz TM-21 mission which will carry U.S. astronaut Dr. Norman Thagard and cosmonauts Lt. Col. Vladimir Dezhurov and Mr. Gennady Strekalov aboard a Soyuz spacecraft to the Mir Station.
- The Mir 18 Main Expedition during which Thagard and his fellow cosmonauts, Dezhurov and Strekalov, will spend approximately three months aboard the Mir Station.
- The STS-71 Space Shuttle mission which will perform the first Shuttle-Mir docking, carry cosmonauts Col. Anatoly Soloviev and Mr. Nikolai Budarin to the Mir Station, and return Thagard, Dezhurov, and Strekalov to Earth.

1.2 Major Finding

In the Task Force's opinion, the joint U.S./Russian program is following sound engineering and medical practices and is managing risk effectively. At this time, there are no unacceptable threats to mission safety for the Soyuz TM-21, Mir 18 Main Expedition, or the STS-71 missions.

1.3 Basis for Confidence

The major finding of the Task Force that the Phase 1A missions face no unacceptable risks is based on data review, interviews, discussions, and site visits conducted by the Review Team in the United States and Russia. At the core of the finding is the conclusion that the interface between the U.S. and Russian civil space organizations is operating effectively and that the processes, hardware, and people necessary to safely complete the Phase 1A missions are in place.

Both the United States and Russia can view their respective records in human space exploration with great pride. As the Review Team came to understand the Russian approach, it became clear that the far-reaching achievements of the

¹ See Appendix 1 for a listing of the Review Team members.

² Phase 1A includes the STS-60 and STS-63 Shuttle missions which have already been completed.

Soviet/Russian space effort are based on an approach which varies from that of the U.S. more in style than in substance.

In Russia, as in the United States, the design, development and manufacturing of human space flight hardware is very strictly managed and subject to rigorous requirements, standards, and procedures. A recent NASA review headed by the NASA Marshall Space Flight Center (MSFC) in preparation for the International Space Station Alpha (ISSA)³ found that in almost all cases Russian standards are equivalent to NASA standards. In reviewing Russian safety, reliability, and quality assurance processes, Review Team members reached a similar conclusion.

The review of Russian hardware reinforced the impression that the necessary processes are in place and are functioning effectively. While much debated, the condition of the Baikonur Cosmodrome continues to support launch operations at a high level. Proton, Soyuz, and other launch vehicles and their payloads are assembled, tested, fueled, and launched to support civil and defense needs. In 1994, a total of 30 launches (11 Soyuz, 13 Proton, 4 Zenit, 1 Tsiklon, and 1 Rokot) were made from Baikonur with no failures.

The A-2, or Soyuz, booster which will be used for Soyuz TM-21 has been responsible for over 1000 successful launches as of this report, more than the total for all U.S. Atlas, Delta, Titan, and Shuttle launches combined. It has been used for every manned Soviet and Russian launch. The table below provides a summary of the reliability of this launch system.

Last 20 Flights	100% (20/20)
Last 5 Years	100% (133/133)
Last 10 Years	100% (339/339)
Total since 1963	93.1% (1008/1083)

Table 2. Soyuz Booster Reliability⁴

The Mir Station has been in orbit since February 1986 and has been supported by a steady stream of Soyuz manned spacecraft and Progress

³ "International Space Station Alpha Program: NASA/RSA Assessment of Russian Specs and Standards Applied to the Russian Segment", January 17, 1995.

⁴ Aviation Week and Space Technology, February 20, 1995, p. 44.

unmanned supply vehicles; a total of 51 crewmembers, including 11 foreign cosmonauts, have flown on the Mir Station.

As to the final critical element--people--discussions with the NASA personnel who have been involved in the Phase 1 program and direct interactions during the site visits in Russia led the Review Team to conclude that professional, technically competent people are in place throughout the Russian space infrastructure. In addition, strong working relationships between Russian and U.S. counterparts have developed and are continuing to mature. These relationships have fostered a sense of mutual trust which is absolutely essential to the success of not just Phase 1, but the entire International Space Station program.

The most striking example to date of this mutual trust can be found in the recently concluded STS-63 Shuttle mission which included a rendezvous with the Mir Station. The decision on the part of the Russian team to allow Discovery to approach to within 10 meters of the Mir Station despite the anomaly in the Orbiter Reaction Control System (RCS) thrusters was a clear expression of the Russian team's trust in the systems knowledge, processes, and operations management of the U.S. team.

The Review Team concluded that the Soyuz TM-21/Mir 18 Main Expedition prime and backup crews have received extensive training and are prepared for the overall mission. On February 17, 1995, the prime and backup crews completed certification testing; both received an overall rating of "outstanding". This readiness certification of the crewmembers took place after completion of a comprehensive, three day, graded evaluation of crew performance.

The STS-71 mission has already been the subject of considerable review by the overall Task Force. Development Test Objective (DTO) results to date have confirmed the accuracy of engineering models and demonstrated the completeness and accuracy of training and procedures. Flight data, demonstrations, and data analysis results continue to add to the confidence that the STS-71 mission as planned will meet its objectives successfully with the desired safety margins.

1.4 Additional Findings - Phase 1A

In addition to the major finding that it is safe to proceed with the Phase 1A missions, there are several additional findings relating to Phase 1A which

have emerged from the review process (the reference numbers refer to the specific section in the body of report which contains the recommendation):

- **The Phase 1 Program Office should reassess adequacy of Mir Station communications coverage to enhance mission safety as well as mission success. (Reference 3.3.2.1)**
- **Given the limited time remaining until the Soyuz TM-21 launch, the following recommendations for on-site medical support and emergency preparations at Baikonur must be acted upon immediately:**
 - **The NASA flight surgeons at the Baikonur launch site must be provided with an independent communications capability allowing direct access to the NASA Johnson Space Center (JSC).**
 - **A NASA flight surgeon must be cleared to accompany the Soyuz TM-21 U.S. crewmember from Baikonur to Moscow in the event a medical evacuation is required.**
 - **All NASA personnel working at the Baikonur Cosmodrome must be immunized against Hepatitis B.**
 - **The NASA flight surgeons should be supplemented with a Registered Nurse/Emergency Medical Technician since the flight surgeons will not be working in close proximity to one another at the launch site. (Reference 3.3.4.1)**
- **Prior to the TM-21 launch, NASA must investigate the clinical resources available for treatment of the U.S. crewmember as well as the practical options for transferring care of the crewmember to U.S. care at the Chkalovsky Air Base, including medical evacuation to the U.S. Air Force Base at Ramstein, Germany. (Reference 3.3.4.2)**
- **Medical communications between the Institute for Biomedical Problems (IBMP) and NASA JSC should be by dedicated service available throughout the Phase 1A missions. (Reference 3.3.4.3)**
- **The Joint Medical Support Plan should be agreed upon and implemented promptly to avoid potential conflicts during the course of the missions. (Reference 3.3.4.4)**
- **NASA must tailor expectations for science during the Mir 18 Main Expedition due to the late arrival of experiment hardware and flight procedures. Emphasis in the science area should focus solely on astronaut Thagard's efforts to characterize the Mir Station environment and provide valuable lessons on how to best achieve U.S. scientific goals aboard Mir Station. The successful completion of specific experiments**

should be viewed within this context rather than as a separate measure of success. (Reference 4.2.3.1)

- **If the assistance of a cosmonaut is not available during the Mir 18 Main Expedition to conduct time critical experiments, the experiments which require that assistance should be rescheduled. (Reference 4.2.3.2)**
- **The remaining invasive protocol for Mir 18 Main Expedition crewmembers, the calcium-chloride infusion scheduled to occur aboard the Shuttle during STS-71, should be carefully reviewed by medical operations before implementation. (Reference 4.2.3.4)**

1.5 Additional Findings - Post-Phase 1A

There are several additional findings relating to the missions beyond Phase 1A which have emerged from the review process (the reference numbers refer to the specific section in the body of report which contains the recommendation):

- **Every effort should be made to retain key U.S. personnel who serve as interfaces to Russian organizations in their respective positions. (Reference 3.1.1)**
- **Reciprocal U.S./Russian payload safety certification should be assessed. (Reference 3.2.3.1)**
- **All U.S. crewmembers who will be serving on the Mir Station must be identified no less than two years prior to their mission in order to begin the necessary language training. (Reference 3.3.3.1)**
- **It is imperative that flight and training hardware for U.S. experiments as well as flight procedures for U.S. experiments be available in Russia in accordance with a jointly agreed upon schedule. In the event that the necessary items are not available within that schedule, the experiment should be postponed or cancelled. (Reference 4.2.3.3)**
- **Implementation of NASA institutional automated data processing and telecommunications (ADP/T) capabilities in Russia must be given a high priority. (Reference 4.2.3.5)**

2 INTRODUCTION

2.1 Background

In October 1992, Russia and the U.S. formally agreed to conduct a fundamentally new program of human cooperation in space. This original "Shuttle-Mir" project encompassed combined astronaut-cosmonaut activities on the Shuttle, Soyuz, and Mir Station. In November 1993 the scope of the planned cooperation was expanded considerably and became Phase 1 of the International Space Station Alpha program. This expanded program combines the original Shuttle-Mir program with additional Shuttle flights to the Mir Station and U.S. crews aboard the Mir Station.

Phase 1 represents the building block to create the experience and technical expertise for an International Space Station. The Phase 1 program brings together the United States and Russia in a major cooperative and contractual program that takes advantage of both countries' capabilities.

The content of the Phase 1 program consists of the following elements as defined by the Phase 1 Program Management Plan, dated October 6, 1994:

- Up to ten Shuttle-Mir rendezvous and docking missions between 1995 and 1997
- Astronaut long duration presence on Mir Station
- Requirements for Mir Station support of Phase 1 when astronauts are not on board
- Outfitting Spektr and Priroda modules with NASA science, research, and risk mitigation equipment
- Related ground support requirements of NASA and the Russian Space Agency (RSA) to support Phase 1
- Integrated NASA and RSA launch schedules and manifests

The primary advantages of Phase 1 are that "it will provide valuable experience and test data that will greatly reduce technical risks associated with the construction and operation of the International Space Station. The Space Station Program will be enhanced by combined space operations and joint space technology demonstrations. Moreover, Phase 1 will provide early opportunities for extended [duration] scientific and research activities."⁵

⁵ "Addendum to Program Implementation Plan", 1 November 1993, p. 1.

2.2 Shuttle-Mir Task Force Charter

In May 1994, the Task Force on the Shuttle-Mir Rendezvous and Docking Missions was established by the NASA Advisory Council. Its purpose is to review Phase 1 (Shuttle-Mir) planning, training, operations, rendezvous and docking, and management and to provide interim reports containing specific recommendations to the Advisory Council.

The first meeting of the Task Force was held at the Johnson Space Center (JSC) on May 24 and 25, 1994 with a preliminary report submitted to the NASA Advisory Council on June 6, 1994. The second meeting of the Task Force was held at JSC on July 12 and 13, 1994 and a detailed report containing a series of specific recommendations was submitted on July 29, 1994. The third Task Force meeting was held at JSC on October 11 and 12, 1994. The briefings presented at that meeting reviewed NASA's response to the Task Force recommendations made to date and provided background data and current status on several critical areas which the Task Force had not addressed in its previous reports. The third report, released on November 2, 1994, focused on management; mission requirements; the Orbiter Docking System (ODS); plume, docking, and mated loads; and rendezvous and docking.

On December 6, 1994, NASA Administrator, Mr. Daniel Goldin requested that Lt. Gen. Thomas P. Stafford, in his role as the chairman of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions, "lead a team composed of several Task Force members and technical advisors to Russia to review preparations and readiness for the upcoming international Space Station Phase 1 missions."⁶

The Russian Space Agency (RSA) identified Academician Vladimir Utkin, Director of the Central Scientific Research Institute for Machine Building (TsNIIMASH), as Gen. Stafford's counterpart in this effort.

In his directions to Gen. Stafford's Russian Review Team, Mr. Goldin requested that the team focus its initial efforts on safety of flight issues for the remaining Phase 1A missions:

⁶ Letter, Mr. Daniel S. Goldin, NASA Administrator, to Lt. Gen. Thomas P. Stafford, Chairman of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions, December 6, 1994 (see Appendix 2).

- The Soyuz TM-21 mission which will carry U.S. astronaut Dr. Norman Thagard and cosmonauts Lt. Col. Vladimir Dezhurov and Mr. Gennady Strekalov aboard a Soyuz spacecraft to the Mir Station.
- The Mir 18 Main Expedition during which Thagard and his fellow cosmonauts, Dezhurov and Strekalov, will spend three months aboard the Mir Station.
- The STS-71 Space Shuttle mission which will perform the first Shuttle-Mir docking, carry cosmonauts Col. Anatoly Soloviev and Mr. Nikolai Budarin to the Mir Station, and return Thagard, Dezhurov, and Strekalov to Earth.

Mr. Goldin requested that the Review Team complete the review and submit its final report prior to March 1, 1995.

2.3 Methodology

Given the compressed schedule for the review activity, Gen. Stafford assembled a Preliminary Working Group, led by Maj. Gen. Joe H. Engle, USAF (Ret.) and composed of several Review Team members⁷. Supported by a number of technical advisors, the Preliminary Working Group worked full-time collecting data, conducting interviews, and carrying out preliminary analysis. Over the course of two months the Preliminary Working Group interviewed a wide range of individuals, including NASA and contractor managers, engineers, and technical staff as well as foreign astronauts who have flown on both Soyuz and Mir Station.

In addition to providing critical background data and surfacing issues, the results of the interviews and meetings were used to plan a series of site visits by the Preliminary Working Group in Russia from January 9 through January 21, 1995. While in Russia the Preliminary Working Group visited the Russian Space Agency, Khrunichev State Research and Production Space Center, Central Scientific Research Institute of Machine Building (TsNIIMASH), Mission Control Center - Moscow (MCC-M), Rocket Space Corporation - Energia (RSC-Energia), Gagarin Cosmonaut Training Center (GCTC), and the Institute for Biomedical Problems (IBMP).

The Preliminary Working Group also held discussions with the Directors of the NASA Liaison Office and the Space Station Technical Liaison Office in Russia as well as members of their technical staff; Mr. Vladimir Sambaiew, Environment, Science, and Technology Counselor to the Ambassador; and Dr. Nicholas Riesland, Embassy Resident Medical Officer.

⁷ See Appendix 3 for a listing of the Preliminary Working Group members.

On January 31 and February 1, 1995 the Preliminary Working Group briefed Gen. Stafford and the entire Review Team at the Kennedy Space Center. This included an overview of general observations applying to all phases of Phase 1A such as Russian design, manufacturing, and safety processes as well as the principles for joint operations. It also included specific preparations for the individual Phase 1A missions.

On February 1 - 2, 1995 the Review Team met with Academician Utkin and a number of his technical advisors at the Kennedy Space Center. In addition to discussions relating to preparations in Russia for Phase 1A, NASA preparations for the STS-71 mission were reviewed and detailed responses to Academician Utkin's questions provided.

On February 6, 1995 the Review Team was briefed on the status of the Phase 1A missions by senior NASA officials. This included discussions with the Administrator, the Acting Chief Engineer, the Associate Administrator for Space Flight, the Phase 1 Program Manager, the Associate Administrator for Life and Microgravity Sciences and Applications, his deputy, and the Associate Administrator for Safety and Mission Assurance.

Between February 7 - 18, 1995, the Review Team travelled to Russia for a series of meetings, interviews, and site visits, including the Russian Space Agency, Khrunichev State Research and Production Space Center, TsNIIMASH, MCC-M, RSC-Energia, GCTC, and IBMP. While in Russia, the Review Team travelled to the Baikonour Cosmodrome in Kazakhstan on February 15 to observe the launch of Progress M-26. Two days later, the Review Team witnessed the automatic docking of Progress M-26 to the Mir Station from MCC-M.

On February 19, 1995, an open meeting of the Task Force was held at NASA Headquarters. Notice of this meeting was posted in the Federal Register per the Federal Advisory Committee Act. At this open meeting, the Review Team members presented their findings and observations. From that discussion, the findings contained in this report were developed.

3 GENERAL OBSERVATIONS

3.1 Processes, Hardware, and People

OBSERVATIONS

It is the opinion of the Review Team that the NASA and Russian processes as well as the hardware and people interfaces are working effectively.

Processes

The Review Team drew heavily on the work of NASA's joint working groups and technical experts whose efforts began back in August 1993. This work has involved extensive discussions with Russian technical experts as well as in-depth penetration of Russian hardware and subsystems design and performance including engineering specifications and standards.⁸ In concert with their findings, it is the conclusion of the Review Team that the necessary processes (e.g., design, manufacturing, safety, operations, etc.) are in place.

The Central Scientific Research Institute for Machine Building (TsNIIMASH) and the State Acceptance Verification Board are the two principal participants in the safety, reliability, and quality assurance involved in these processes. TsNIIMASH provides independent review and approval at each stage of the development and acceptance process including customer acceptance testing. The State Acceptance Verification Board certifies flight hardware and software prior to each flight including prelaunch operations (similar to NASA's Flight Readiness Review).

Hardware

The effectiveness of the processes is evidenced by the highly successful record of the Russian space program. Over the past 10 years the performance record of the Soyuz booster has been perfect -- out of 339 launches of the Soyuz booster there have been no failures⁹. The Mir Station

⁸ Examples of the studies conducted in this area include "The Russian FGB Tug/Energy Block Assessment", October 1993; "Technical Assessment of Mir-1 Life Support Hardware for the International Space Station", March 1994; and "International Space Station Alpha: NASA/RSA Assessment of Russian Specs and Standards Applied to the Russian Segment", January 1995.

⁹ Aviation Week and Space Technology, February 20, 1995, p. 44.

is also proven hardware. There is a program in place to recertify it annually as well as before each mission; to maintain it through regular and as-needed replacement of component; and extend its lifetime as well as enhance its capabilities. However, certain system margins and vulnerabilities require continued attention.

People

Discussions with the NASA personnel who have been involved in the Phase 1 program and direct interactions during the site visits in Russia, led the Review Team to conclude that professional, technically competent people are in place throughout the Russian space infrastructure. Strong working relationships between Russian and U.S. counterparts have developed and are continuing to mature. These relationships have fostered a sense of mutual trust which has manifested itself in a number of ways. Examples include:

- The effectiveness of the joint working groups in addressing areas such as Management; Safety Assurance; Flight Operations and Systems Integration; Mission Science; Crew Training and Exchange; Mir Operations and Systems Integration; Extravehicular Activity; and Medical Operations. These management and technical forums have generated numerous decisions and agreements in which one party accepted the technical recommendation of the other based on available supporting data plus respect for the other's capabilities and record.
- The willingness to address technical questions of the Review Team during the site visits in Russia.
- The joint operations conducted during STS-63. This is perhaps the most striking example to date as it involved hardware and people operating cooperatively in space as well as on the ground. No better example of the trust which has developed on both sides exists than the decision of the Russian team to allow Discovery to approach within 10 meters of the Mir Station despite the anomaly in the Orbiter Reaction Control System (RCS) thrusters. In making that decision, the Russian team depended largely on the assurances of the NASA team that the Mir Station was not endangered by allowing the approach to proceed.

A principal element in the development of mutual trust is the continuity of the NASA team. For the Russians, many of whom have been working within the same area for years and even decades, it is important to deal with the same individuals on the NASA side over time. Only through this continuous exposure and common effort can the necessary joint technical proficiency

and trust be established. Should a replacement be made on the NASA side, this process essentially begins again. Likewise, the introduction of too many NASA participants into the process can be confusing and make it difficult for the Russian participants to determine who is authorized to act on specific issues. A number of Russian officials also commented to Review Team members on the negative impact that large numbers of NASA visitors (i.e., those requesting tours of facilities without a pressing reason to make such a visit) is having on their ability to get work done.

RECOMMENDATION

3.1.1 Every effort should be made to retain key U.S. personnel who serve as interfaces to Russian organizations in their respective positions.

3.2 Development

3.2.1 Russian Engineering Design and Manufacturing

OBSERVATIONS

There is no question that differences exist between NASA engineering design and manufacturing processes and those in place in Russia. As a recent study of Russian specifications and standards observed, however, "this is to be expected and would be encountered in any ... assessment of a U.S. aerospace contractor's specifications and standards."¹⁰ The report went on to cite a number of specific differences including:

- RSA [Russian Space Agency] relies on operator/technician expertise versus written requirements for process control
- Limited number of Russian vendors/suppliers/contractors eliminates many verification requirements
- All Russian enterprises generally use the same specifications/standards and requirements
- RSA uses more damage tolerant (low strength, ductile, etc.) materials
- Significant amount of verification testing is used by RSA to determine if components meet end use requirements
- RSA relies on lot-to-lot testing to verify specification minimums versus material design allowables with a statistical basis¹¹

¹⁰ "International Space Station Alpha Program: NASA/RSA Assessment of Russian Specs and Standards Applied to the Russian Segment", January 17, 1995, p. 26.

¹¹ Ibid, p. 27.

During the Review Team site visits and discussions in Russia, its members encountered these differences and a number of others as well. The source of these differences are the diverse paths which the U.S. and Russian space programs have pursued over the past forty years.¹² Many factors such as available resources and technology influenced these independent courses; however, the reliability and safety of the end products of the two programs are not significantly different.

The Russian engineering design and manufacturing process, as related to members of the Review Team, consists of 26 steps divided into four stages. The engineering design process is an iterative one in which a pattern of testing, followed by modification, followed by retesting is used extensively.¹³ The 26 steps are based on standards set by the Russian government to which very little change is allowed without a significant review cycle.

In addition, the accumulated experience of the Russian aerospace industry is impressive as is the long-term commitment of management, engineers, and technicians to their individual firms. Many individuals in the Russian industry have spent their entire career in the same organization and, oftentimes, within a given program.

Based on the site visits and the many discussion with Russian technical personnel, the Review Team concluded that while the NASA and Russian engineering design and manufacturing processes differ in many areas, the Russian processes are thorough and effective. The Team saw no evidence that the Russian processes in any way compromise safety.

¹² See Appendix 4 (Russian Engineering Design and Manufacturing Process).

¹³ One aspect that highlights the different paths taken by the U.S. and Russia is the evolutionary nature of Russian development. This is evidenced by the vehicles involved in Phase 1. The two-and-a-half stage Soyuz rocket has over 1000 launches to its credit since 1963. The Soyuz spacecraft has been in use since the late 1960s. The modules of the Mir Station have evolved from the Salyut series of Russian space stations which first saw service in the early 1970s.

3.2.2 Testing Philosophy and Test Articles

OBSERVATIONS

The Russian certification test network appears to be just as sophisticated and comprehensive as the NASA certification test network. All levels of ground testing are conducted including component tests, qualification tests, subsystem tests, system tests, and integrated system tests.

A wide range of test articles are produced and tested from the design stage through flight and on through the on-orbit lifetime of the flight unit. Examples include the mock-up and manufacturing aid; structural test article; thermal vacuum test article; propulsion system test article; electrical analog article; life support test article; and crew training simulators.

The Russian approach has advantages. One important example is the practice of maintaining a full-scale integrated test version of the flight article on the ground. This "fleet leader" provides the capability to monitor ongoing systems performance and aid in anomaly resolution, life prediction, and hardware compatibility checkout before launch.

3.2.3 Safety Assurance

OBSERVATIONS

In order to fully understand the Russian approach to safety and reliability one must first understand the critical role TsNIIMASH plays in the Russian space program.

TsNIIMASH

The Central Scientific Research Institute of Machine Building (TsNIIMASH) maintains the safety and reliability standards for operations in space. They have a major responsibility for hardware certification during development of every Russian spacecraft from design through operation.

TsNIIMASH, as it has been called since 1967, was founded in 1946 as the chief research organization in the missile and space industry of the USSR... TsNIIMASH has been a leading Institute in the Russian space industry performing the following work:

- basic scientific and systems analysis research to determine the basic directions of development and the technical appearance of future space and missile technology (launch vehicles, manned and automatic spacecraft, orbital stations) and preparation and expertise in the space programs;
- theoretical and experimental space research of aerogasodynamic, acoustic, and thermal loads in the atmosphere of the earth and other planets and in outer space, work on thermal resistance of heat protection in high temperature gas currents, computational/theoretical research and experimental work on design strength under conditions of static, vibrodynamic, impact, and thermal loads;
- flight control of spacecraft, research and development on original methods and algorithms for solving control, ballistics, and navigation tasks, development of methods and means of flight control in orbit, during orientation, stabilization and maneuvering in orbit, and during descent and landing of products of missile and space technology; and
- ensuring reliability of missile and space technology, standardization and product uniformity, certification and quality control. This includes detailed expert opinions on the project documentation by the organizations developing space vehicles, launch vehicles, and basic systems as well as instruments. It also includes expert opinions on the progress of productions and the adequacy of ground work on basic products in the industry.¹⁴

TsNIIMASH is composed of eight directorates with approximately 8,500 employees. These directorates are the Center of Systematic Design, Center of Systematic Research, Space Flight Control Center (Mission Control Center - Moscow), Center of Research and Experimental Works, Center of Heat Exchange Research, Center of Aerogas Dynamics Research, Center of Strength Research, and Technical/Engineering Services.

Because of their long history and extensive role, TsNIIMASH possesses the large body of historical data used to address specific design and engineering issues. This is particularly significant since Russian hardware design is evolutionary; prior space heritage is evident back to Vostok. As with the design and manufacturing process, the senior managers, engineers, and technicians involved in the safety and reliability assurance process have been in place for an

¹⁴ Igor A. Reshetin (General Director, TsNIIMASH Export), "The International Work of TsNIIMASH in the Field of Space Research", a paper presented at Draper Laboratories on March 16, 1994.

extended period of time (most since Gagarin's flight on April 12, 1961) and represent a valuable resource.

TsNIIMASH's role in safety, reliability, and quality assurance spans the entire product lifecycle. It is responsible for the development of standards, review of their implementation in design, manufacture and test, approval of the ground certification plan, the processing of waivers, determination of system margins, certification of life extension, review of flight anomalies and corrective actions, etc.

TsNIIMASH is the independent oversight arm of RSA and as such also conducts customer acceptance testing; it provides the guarantee of performance, safety and reliability¹⁵.

Extensive documentation is developed during each stage of the design, manufacturing, and testing process. This data package is termed the "passport" and is critical in the reliability assurance program. Configuration management of documentation is maintained through central control of the documents. The State Verification Acceptance Board issues a certification statement based on the following elements:

- Designer information
- Manufacturing information which includes the "passport" package completed for each manufacturing step
- "Expert opinion letters" or expertise statements
- Prelaunch operations manual

Safety, Reliability, and Quality Assurance (SR&QA) Process

Design, development, and manufacturing of Russian human space flight hardware is strictly managed; all components including the launch vehicle are specially controlled as safety critical and are traceable. Rigorous requirements, standards, and procedures are in place. A recent review by MSFC in preparation for Space Station found that in almost all cases equivalency to NASA's standards existed.¹⁶ Every step in the design, development, and certification phase is determined by documents agreed to at the beginning. Two

¹⁵ See Appendix 5 (Flight Certification Process).

¹⁶ "International Space Station Alpha Program: NASA/RSA Assessment of Russian Specs and Standards Applied to the Russian Segment", January 17, 1995.

documents: the design, development, test, and evaluation plan and the safety and reliability assurance plan are mandatory for program approval and the Authority To Proceed. These must be coordinated with TsNIIMASH and other institutes as appropriate (e.g., Institute of Thermal Processes, Institute for Mechanical Processes, etc.) A program phase is considered complete only when it has received cognizant institute and TsNIIMASH approval. Institutes review sufficiency of the technical program and reliability assurance program and participate in major integrated tests.

During hardware manufacturing, military representatives from the Ministry of Defense and/or the Military Space Forces are on-site to provide government oversight. Performance waivers and deviations are referred back to the cognizant Institutes for Technology and TsNIIMASH for disposition and approval. Safety-critical deviations receive a special review. When explicitly asked, RSA, Khrunichev, RSC Energia, and TsNIIMASH all stated that the proper execution of requirements and standards has not been affected by the breakup of the U.S.S.R. Full oversight of manufacturing by the military, applying the same standards as those in force prior to the breakup of the Soviet Union, continues within the Ukraine and Kazakhstan. All previous requirements are still in force.

In addition to the above testing and development review process, a military acceptance team also monitors the process. This team is a separate, independent group not subordinate to RSA or the customer and not paid by the customer.

Readiness of the flight article to enter its next phase (e.g., Preliminary Design Review, Critical Design Review, Acceptance, Preshipment, etc.) is determined only after all testing and analysis have been completed and all comments taken into consideration.

For manned space launches, the determination is made by the Special State Commission under the leadership of Col. General Ivanov (Commander in Chief of the Military Space Forces), Mr. Boris Ostroumov, deputy RSA chief, and Mr. Semenov, General Director, Energia. All other interested parties are represented including builders, users, government agencies, and Institutes.

Software Independent Validation and Verification (IV&V)

Software IV&V is one example where Russian standards differ significantly from United States established practices. Khartron in Kharkov, Ukraine produces the software for the Soyuz (A-2) launch vehicle. RSC Energia produces software for the Soyuz and Progress spacecraft as well as the Mir Station and modules. No IV&V is performed on these software products during any phase. Although internal review processes were reported to be in place at Khartron and RSC Energia, no independent audits or IV&V are performed. However, this software is much simpler and less integrated than that found in the Shuttle. To date no software problems have been identified in the Soyuz (A-2) launch vehicle.

Safety and the Launch Process

The Special State Commission also assesses readiness at a variety of stages in the prelaunch process (e.g., prior to pad rollout, prior to launch, etc.). Safety does not have a representative on the Commission; however, the Commission receives reports from each group of specialists responsible for various systems and ground services with safety represented in each group.

The last decision is made four hours prior to launch by the Commission. At that time a final report by TsNIIMASH and the Military Space Forces is presented. All on the Commission must be "go" for launch. Anomaly resolution during the final countdown similarly requires full consensus.

OBSERVATIONS - PAYLOAD SAFETY CERTIFICATION

Currently, any Russian equipment flown aboard the Shuttle is subject to payload safety certification. U.S. equipment flown aboard Soyuz, Progress, and Mir Station requires Russian certification. This process could be greatly simplified if the experience and maturity of each country's system would be recognized by the other. Serious consideration should be given to accepting the safety certification of the other partner's testing.

RECOMMENDATION

3.2.3.1 Reciprocal U.S./Russian payload safety certification should be assessed.

3.3 Operations Principles

3.3.1 Roles and Responsibilities

OBSERVATIONS

Each country will be responsible for the following:

- Planning, training, execution and control of their respective spacecraft and its mission.
- Safety of astronauts and cosmonauts on-board their respective spacecraft – Soyuz, Mir Station, and Shuttle.
- Operations of its own control center and network systems, with technical personnel in the other country's control facilities and participation as appropriate.

Each country will be responsible for adequate coordination with the other side when conditions may cause:

- Major changes to plans.
- Potential safety or health impacts to the crew.
- Possible interactive effects on the other vehicle or operation (e.g., the leak in an RCS thruster during the STS-63-Mir Station rendezvous and proximity operations)

In the discharge of these roles and responsibilities, it is necessary to understand the similarities and differences between the two country's operations and the different roles between the on-board crew and the Mission Control Center. The Russian concept of mission control is, for the most part, similar to NASA's. The most significant difference is the philosophy of preparation for anomalous performance of spacecraft or crew. The Russian approach to preparation for anomalies is to train intently only for life-threatening events. Less than life threatening anomaly preparation does not include intensive ground-based training, although procedures may be prepared in advance. A frequent result is that mission objectives are not completed while the crew or MCC-M prepares to correct the anomaly, but crew safety is not reduced.

MCC-M is responsible for command and control of the mission following separation from the launch vehicle. The generic responsibilities are:

- Monitoring and analysis of spacecraft systems performance.
- Daily flight planning.
- Tracking, orbit prediction and maneuver planning.
- Crew health monitoring.
- Supporting experiment operations.
- Generating and uplinking commands.
- Providing data to payload sponsor organizations.
- Providing spacecraft systems data to remotely located systems specialists.
- Managing and assuring the support of the tracking and communications network.
- Communicating information to the search and rescue forces.

A Lead Flight Director has overall mission command and control responsibility, similar to a combination of NASA's Lead Flight Director and JSC Mission Operations Directorate (MOD) Manager positions in the MCC-H. A small team of NASA technical personnel also are located in the MCC-M during periods when U.S. astronauts are on-board.

The MCC-M team consists of four shifts of personnel. Each shift is led by a Shift Flight Director whose responsibilities are comparable to those of his NASA counterpart. Each team is staffed with specialists to perform the tasks necessary to accomplish the above functions.

The flight crew is responsible for:

- Executing the flight plan.
- Manually controlling on-board systems when necessary.
- Monitoring on-board displays.
- Maintaining and repairing on-board systems.
- Taking immediate action to safe critical situations.

3.3.2 Mission Management, Communications, and Methods

OBSERVATIONS - RUSSIAN AUTONOMOUS MISSION PHASES

For Soyuz TM-21 rendezvous and the Mir-18 Main Expedition, MCC-M has unilateral responsibility for mission management. The Russian chain of command follows the same principles as the NASA mission

management protocol. MCC-M is responsible for mission continuation decisions. The on-board commander is responsible for safety related decisions requiring immediate action. MCC-M originated deviations from planned activities are coordinated between MCC-M, support elements, and the crew.

MCC-M provides flight plan information, on-board systems monitoring, management and performance analysis. MCC-M also provides orbit determination, maneuver planning, and state vector updates. The crew has wide latitude in scheduling and performing routine maintenance or repair activities.

The crew can terminate or take over manual control of station keeping and docking activity. In an emergency, the crew can evacuate the Mir Station by retreating to the Soyuz spacecraft and separating from the station. This does not require ground control.

OBSERVATIONS - STS-71 MISSION

For STS-71, mission management is based on the principle of shared responsibility for interactive periods between the two spacecraft (Mir Station and Atlantis). While docked, MCC-M and the Mir 18 Main Expedition commander are responsible for crew health and safety as well as protection of vehicle assets on the Mir Station side of the docking interface. Likewise, MCC-H and the Shuttle commander are responsible for crew health and safety as well as protection of vehicle assets on the Shuttle side of the docking interface.

Detailed plans, procedures, and protocols are defined for nominal joint activities. A process for coordinating in-flight changes between MCC-H and MCC-M as well as between the crews has been defined. Mission rules are established for responsibility and response to identified contingencies during rendezvous, station-keeping, docking and docked flight.

Dedicated, redundant communication links between MCC-H and MCC-M as well as the Atlantis-Mir Station VHF communication system provide the capability to assure a coordinated execution of the mission.

OBSERVATIONS - MCC-M AND SOYUZ/MIR STATION COMMUNICATIONS

In January 1991 the fleet of ocean-going tracking ships was phased out of Mir Station operations to save funds. Some of the ships continue to operate to support unmanned missions and could step in as a backup when needed to support Mir Station. By mid-February, the Mir Station was spending up to 9 continuous hours out of contact with MCC-M because of tracking system cutbacks.¹⁷

The elimination of the ocean-going tracking ships has left MCC-M to Soyuz/Mir Station communications reliant upon the six Russian national ground stations and the Luch communications satellite network. These systems provide voice, telemetry, television (uplink and downlink), command, and tracking modes.

The extended Loss of Signal (LOS) time under which the Mir Station often operates was a contributor to the chain of events which resulted in the electrical power emergency aboard Mir Station in October 1994 (discussed further in the Mir Station Systems section of this report). Until recently, Russian satellite communications capability relied upon a single Luch satellite. A second Luch relay satellite was launched in December 1994 and has been incorporated into the communications network. Use of this capability was demonstrated during the STS-63 "fly-around" which occurred on February 8, 1995 and the Progress M-26 rendezvous and docking on February 17, 1995.

RECOMMENDATION

3.3.2.1 The Phase 1 Program Office should reassess adequacy of Mir Station communications coverage to enhance mission safety as well as mission success.

OBSERVATIONS - MCC-M AND MCC-H COMMUNICATIONS

For STS-71 twelve voice lines (loops) are planned between MCC-M and MCC-H. The number of loops planned for the Mir 18 Main Expedition are less than for STS-71 because there are fewer requirements. Communications requirements will, for the most part,

¹⁷ David S. F. Portree, "Mir Hardware Heritage", NASA/JSC (JSC 26770), October 1994, pp. 130-131.

be limited to the U.S. technical personnel in Moscow and the medical experiment personnel in Houston. For STS-71, voice and facsimile data will be transmitted across the loops for mission coordination and joint command and control.

Interpreters are provided by both sides for real time voice communications and facsimile message translation.

Plans and protocols are established for:

- Communications loop management, both nominal and contingency.
- Planned communications sessions for data exchanges, vehicle status reports, state vector transmission, and joint mission rule implementation
- Unscheduled sessions for changes to procedures, documentation, or for attitude change requests.
- Language utilization between MCC-H and MCC-M and between spacecraft.

Utilization of these loops is practiced during joint simulations.

3.3.3 Training

OBSERVATIONS

Crew training is the responsibility of the Gagarin Cosmonaut Training Center (GCTC) in Star City, Russia located 40 km northeast of Moscow. Normal and emergency training for all phases of the Soyuz TM-21 mission and Mir 18 Main Expedition were conducted using simulators of varying degrees of fidelity located in and around Star City. Overall crew training provided by GCTC was evaluated as being professional and thorough.

Training sessions take approximately fourteen months and are conducted in Russian. The first several months are lightly loaded in technical material to allow foreign crewmembers to become proficient at the working level with both written and spoken Russian language. Although language training also is conducted at Star City during these first few months it is critical that the crewmembers arrive at Star City with at least a conversational grasp of Russian. Six months of full-time language training is considered to be the minimum time necessary to arrive at this proficiency for non-Russian speakers. Crew

selection must be early enough to allow for dedicated, specialized language training prior to arrival in Russia.

In the case of cabin pressure loss, the crew has been trained in leak detection and emergency repair procedures. A special vacuum chamber facility located at Chkalovsky Air base, Star City is used for this training. A flight-representative Mir core module, Kvant II and Soyuz are located inside the vacuum chamber. During training the crew practices leak detection and isolation procedures. Training is conducted under flight-like conditions with the exception that drag-through ventilation ducts and electrical wiring are not present.

Systems training and periodic testing is conducted on all aspects and phases of Soyuz and Mir Station operations. Flight readiness certification of the crewmembers only takes place after completion of a comprehensive, three day, graded evaluation of crew performance. One day each is allotted for normal and emergency procedures associated with:

- Launch, rendezvous and docking
- Orbit operations
- Deorbit and landing.

Evaluation is conducted under realistic conditions and the crew are in pressure suits for launch, rendezvous and docking, deorbit and landing phases. Upon successful completion of all phases, the Commanding General of GCTC and his deputies certify the crew as ready for flight. On February 17, 1995, the Soyuz TM-21/Mir 18 Main Expedition prime and backup crews completed this certification testing. Both crews received an overall rating of "outstanding".

Following certification for flight, additional proficiency training is conducted primarily in the manual rendezvous and docking phases both at GCTC and using similar facilities located at the Baikonur Cosmodrome located in Kazakhstan until the day preceding launch.

Experiment training for the Mir 18 Main Expedition was conducted in Star City and at the Johnson Space Center. Russian training specialists were indoctrinated in the experiments and procedures and were then to provide training in Russian to all crewmembers.

RECOMMENDATION

3.3.3.1 All U.S. crewmembers who will be serving on the Mir Station must be identified no less than two years prior to their mission in order to begin the necessary language training.

3.3.4 Medical Operations

OBSERVATIONS - RESPONSIBILITY FOR CREW HEALTH

Preflight

Responsibility for Soyuz TM-21/Mir 18 Main Expedition preflight medical monitoring and training has been retained by the Gagarin Cosmonaut Training Center (GCTC) staff. NASA flight surgeons have been involved in all aspects of training and preflight medical preparations. As part of the process, NASA provided Russia with complete sets of medical records and annual certifications.

Both the prime and backup crews for Soyuz TM-21/Mir 18 Main Expedition were medically certified on February 8, 1995.

The Russian and U.S. representatives have established a Joint Medical Policy Board to coordinate policy for medical support during Phase 1A. Drs. Arnauld Nicogossian and Sam Pool will represent NASA and Dr. Anatoly I. Gregoriev (Director, Institute for Biomedical Problems) and Gen. Berezhnov (Ministry of Defense) will represent the Russian space effort.

Launch

The responsibility for crew health will be retained by the Gagarin Cosmonaut Training Center staff through the launch phase. If an on pad or launch abort occurs over Commonwealth of Independent States (CIS) territory, responsibility for recovery is relegated to the ground Recovery Force which is operated by the Russian military. Temporary, inflatable "hospital facilities" can be erected on site within thirty minutes and are staffed by Russian anesthesiologists, emergency physicians, surgeons, neurosurgeons, and other support staff members. There is also a hospital in the nearby town of Leninsk; however, its capabilities are unknown. It must be also noted that Hepatitis B is a major health hazard in the Baikonur/Leninsk area.

The details of the Russian emergency medical plan is classified and will not be revealed to the NASA flight surgeons until fourteen days prior to launch.

The NASA flight surgeons are both certified in Advanced Trauma Life Support (ATLS) and Advanced Cardiac Life Support (ACLS) and will be at the launch site. They will participate in the stabilization of the U.S. astronaut and are equipped with self contained emergency medical packs. It is essential that one of the NASA flight surgeons accompany the astronaut if medical evacuation from Baikonur is required. It is also important for the NASA flight surgeons at Baikonur to have an independent means of communication which will allow them to contact MCC-H and/or NASA JSC directly.

The NASA flight surgeons must be supplemented at Baikonur with a Registered Nurse/Emergency Medical Technician (RN/EMT) since the flight surgeons will not be working in close proximity to one another at the launch site. One will be assigned to the launch site and the other downrange. The downrange flight surgeon with the Recovery Forces will require the presence of the RN/EMT. Russian Medevac helicopters are available in Kazakhstan at the launch site and down range to recover the crew and bring them to emergency facilities.

Transportation to Chkalovsky Air Base, Star City will be provided by the Russian Recovery Force. The transportation link from Kazakhstan to Moscow will be by Russian fixed wing aircraft standing by at Baikonur with an approximate flying time of 3.5 hours. The inflight medical capability is appropriate for transport.

RECOMMENDATIONS

3.3.4.1 Given the limited time remaining until the Soyuz TM-21 launch, the following recommendations for on-site medical support and emergency preparations must be acted upon immediately:

- **The NASA flight surgeons at the Baikonur launch site must be provided with an independent communications capability allowing direct access to JSC.**
- **A NASA flight surgeon must be cleared to accompany the Soyuz TM-21 U.S. crewmember from Baikonur to Moscow in the event a medical evacuation is required.**
- **All NASA personnel working at the Baikonur Cosmodrome must be immunized against Hepatitis B.**

- **The NASA flight surgeons should be supplemented with a Registered Nurse/Emergency Medical Technician since the flight surgeons will not be working in close proximity to one another at the launch site.**

Emergency Medical Evacuation

There is no satisfactory medical evacuation (Medevac) plan available through the U.S. Embassy. The U.S. Embassy in Moscow is not authorized to arrange for Medevac capability in the Republic of Kazakhstan. A generic Medevac plan provides air evacuation coordinated through the Second Aeromedical Evacuation Squadron, Ramstein, Germany (AES). AES, in turn, can dispatch the 75th Aeromedical Flight Squadron, Ramstein, Germany, who, with a complement of Flight Surgeons, etc., carry out the Medevac mission. It is estimated that it would take 9 - 12 hours for this resource to reach Chkalovsky Air Base, Star City. This would not coordinate effectively with the 3.5 hour transit from Baikonur to Star City. Commercial Medevac capability is also available to Helsinki, Finland or London, England which would require 4 - 6 hours to reach Chkalovsky Air Base, Star City.

A Walking Blood Donor Program is being set up at the U.S. Embassy in Moscow; however, the program is not currently in operation. A modern medical facility with adequate blood bank facilities is available at the Moscow Clinic (Michurinsky Hospital and Kuntsevo Hospital). The Russian emergency medical system is the only logical resource available at the launch site and the Russian plan for retrieval and transport to Moscow the only plan in place. The official transfer of care for our crewmember should occur at Star City and a protocol for that transfer is not yet in place. Waiting on the tarmac at Star City for the plane from Ramstein could represent a discontinuity of medical services. The Russian plan calls for transfer from Star City to the Rehabilitation Hospital in Moscow.

RECOMMENDATION

- 3.3.4.2 Prior to the Soyuz TM-21 launch, NASA must investigate the clinical resources available for treatment of the U.S. member of the crew as well as the practical options for transferring care of the crewmember to U.S. care at the Chkalovsky Air Base, including medical evacuation to the U.S. Air Force Base at Ramstein, Germany.**

Soyuz TM-21/Mir 18 Main Expedition

The medical monitoring of inflight activities is the responsibility of the Russians; however, the NASA flight surgeons will have real-time input to all medical decisions pertaining to the U.S. astronauts health. In addition, the Houston medical establishment will also have daily briefings to include Mir Station environmental parameters, radiation dosimetry, crew work/rest cycles, and information about crew health. All potentially hazardous inflight medical procedures (e.g., CHIBIS Lower Body Negative Pressure suit) will be monitored by the ground (MCC-M) in real time. Routine medical communications can be arranged on a weekly basis, and will be held as confidential. Because of possible interruptions and delays in service on the Russian telephone system, dedicated communication links must be provided for the medical network.

RECOMMENDATION

3.3.4.3 Medical communications between IBMP and NASA JSC should be by dedicated service available throughout the Phase 1A missions.

Deorbit

The astronauts and cosmonauts will be the medical responsibility of the NASA flight surgeons at JSC.

Postflight

Two teams of three medical specialists, representing the U.S. and Russia, will conduct the post flight examination and rehabilitation. Although a post flight activity plan has been signed, the exact details are still under negotiation. Existing NASA and IBMP postflight protocols are incompatible.

OBSERVATIONS - OPERATIONS RULES FOR MAKING MEDICAL AND LIFE SUPPORT DECISIONS

The staff of the IBMP assured the Review Team that rules for making near real-time medical and life support decisions exist; however, they were not available for our review. It is believed that these decisions are made on a case-by-case, *ad hoc* basis. One can surmise that their procedures are adequate based on the extensive experience of their ground based support system and their documented successes over thirty years of operational experience. The NASA flight surgeons and the Joint Medical Policy Board will be included in all such decisions. The NASA flight surgeons located at MCC-M will be in contact with MCC-H as well as IBMP for assistance.

OBSERVATIONS - CONFLICT RESOLUTION OF MEDICAL ISSUES AND THE JOINT MEDICAL SUPPORT PLAN

In the event of a conflict of opinion, the Joint Medical Policy Board, augmented by key personnel from the MCC-M, will arbitrate and affect a solution. The Joint Medical Support Plan, however, has not yet been signed although multiple iterations have been submitted to IBMP for review. At an operational level the NASA flight surgeons should not be hampered by the lack of such a document. However, for ongoing conflict resolution and mutual programs this plan is absolutely essential and should be completed at the earliest possible date.

RECOMMENDATION

3.3.4.4 The Joint Medical Support Plan should be agreed upon and implemented promptly to avoid potential conflicts during the course of the missions.

TRAINING OF NASA FLIGHT SURGEONS IN MCC-M

A schedule of training events exists and training has begun. Review of the curriculum reveals the training to be quite comprehensive. The major existing problem is how the NASA flight surgeons will schedule their time during the Soyuz TM-21 and the Mir 18 Main Expedition. This could be a significant problem if they also have clinical responsibilities for a subsequent U.S. crew resident in Russia. The availability of NASA flight surgeon time is a critical resource and although it need not be redundant it must be sufficient.

4 SOYUZ TM-21, MIR 18 MAIN EXPEDITION, AND STS-71

4.1 Soyuz TM-21

4.1.1 Status of Baikonur

OBSERVATIONS

The Baikonur Cosmodrome is located at 45.6°N/63.4°E in what is now the Kazakh Republic. It has been a major missile and rocket launch site and test facility since 1955 and has been used for all human space flights since Yuri Gagarin's flight in 1961. To the south of the Cosmodrome is the city of Leninsk (population approximately 40,000) which developed as the administrative center for Baikonur and provides living quarters and other facilities for the staff at Baikonur.

While much debated, the condition of the Baikonur Cosmodrome continues to support launch operations at a high level. Proton, Soyuz, and other launch vehicles and their payloads are assembled, tested, fueled, and launched to support civil and defense needs. In 1994, a total of 30 launches (11 Soyuz, 13 Proton, 4 Zenit, 1 Tsiklon, and 1 Rokot) were made from Baikonur with no failures. On February 15, 1995, the Review Team witnessed the successful launch of a Soyuz booster carrying Progress M-26, a Mir Station resupply mission. The Review Team did not have an opportunity to view the Soyuz processing facility, the Launch Control Center, or the launch pad.

Conditions in the support city of Leninsk continue to show signs of duress with unsafe water supplies and general deterioration. While needing much attention to reverse this trend, operations at Baikonur have not yet been affected and there are no unique issues, without workarounds, that could adversely impact the launch of Soyuz TM-21.

4.1.2 Soyuz Vehicle

OBSERVATIONS - SOYUZ BOOSTER

The A-2, or Soyuz, booster originally saw service in late 1963 with the successful launch of Cosmos 22. This booster has been responsible for over 1000 successful launches as of this report, more than the total for all U.S. Atlas, Delta, Titan, and Shuttle launches combined. It has been used for every manned Soviet and Russian launch. Table 5 below provides a summary of the reliability of this launch system.

Last 20 Flights	100% (20/20)
Last 5 Years	100% (133/133)
Last 10 Years	100% (339/339)
Total since 1963	93.1% (1008/1083)

Table 2. Soyuz Booster Reliability¹⁸

Fueled with kerosene and liquid oxygen, the booster engines can be started and throttled to 100% prior to committing to flight. No crewmember fatalities have been caused by the booster. Two major incidents have occurred involving manned Soyuz launches. The first occurred in April 1975 and involved an improper stage separation. This resulted in a suborbital flight in which the crew landed safely. The second incident, in September 1983, involved a pad fire which demonstrated successful use of the Soyuz Launch Escape System (discussed below).

OBSERVATIONS - SOYUZ SPACECRAFT

The Soyuz TM spacecraft used in Phase 1A consists of three main modules: the orbital module, the service module, and the descent or entry module. The spacecraft is equipped with an automatic docking system, but the docking maneuver may be flown manually by the crew on-board Soyuz. The original Soyuz spacecraft was designed for the moon missions in 1966. Plans for conversion into a space station transport were drawn up in 1970. The Progress resupply spacecraft is a modification of the basic Soyuz design. Since 1977, the sole function of the Soyuz and its derivatives linked with the manned space program has been to support manned space stations. Soyuz-TM is a fourth generation design of the basic vehicle. Incorporation of the new Kurs ("course") approach to docking system is the primary difference between the Soyuz-TM and its predecessor the Soyuz-T. Many

¹⁸

Aviation Week and Space Technology, February 20, 1995, p. 44.

Soyuz-TM modifications were applied to Progress-M, the most recent Soyuz derivative.

The first time a Soyuz flew in space was the unmanned Kosmos 133 mission (November 28-30, 1966). The first manned flight of Soyuz (April 23-24, 1967) ended in tragedy. After what appears to have been a trouble plagued flight, cosmonaut Vladimir Komarov was killed when the shrouds of the primary parachute became tangled causing the spacecraft to impact at a high velocity. In June 1971, following a successful series of Soyuz missions, another Soyuz mission ended tragically:

The Soyuz 11 crew perished during reentry when ... explosive bolts for separating the orbital and service modules from the descent module fired simultaneously, rather than sequentially as planned. The abnormally violent separation jarred loose a 1-mm pressure equalization seal in the descent module which was normally pyrotechnically released at a lower altitude. The atmosphere in the descent module vented into space within 30 sec. The crew wore no space suits, so they rapidly lost consciousness and died.¹⁹

Two years of spacecraft redesign and operational changes followed the Soyuz 11 accident. Once again, crewmembers flew wearing pressure suits.

Despite these setbacks, the basic Soyuz design went on to become the workhorse of the Soviet/Russian human space flight program. It has been in use for nearly 30 years and its flight total exceeds that of Mercury, Gemini, Apollo, and Shuttle combined.

The Soyuz TM spacecraft is equipped with a Launch Escape System (LES) which employs a solid propellant tractor escape motor system providing protection for the first 2½ min. In an abort, pyrotechnics fire below the Descent Module and halfway down the launcher shroud. The LES then pulls the Descent Module/Orbital Module combination free, still in the remaining upper shroud section. Peak acceleration is about 14 g. The 12-nozzle motor fires for about 5 sec. and then four shroud panels pivot outwards to slow the ascent. Smaller tower motors fire to pull the shroud assembly clear for the now-separated Descent Module to fall away. From the pad, the capsule would reach an altitude of 1 km. and land some 2½ km. away, using the 27 m.

¹⁹ Portree, pp. 6-7.

diameter reserve parachute because of its more rapid deployment.²⁰ All six solid propellant braking rockets are used at 0.8 meters altitude to cushion the landing.

The system has seen operational use. On September 26, 1983, the LES was activated via backup radio command to allow cosmonauts Vladimir Titov and Gennadi Strekalov to escape a major fire which consumed the booster and launch pad.

In addition to the hardwired connection from the launch control center, two redundant, independent radio command links are available to activate the LES in the event of launch pad abort.

4.1.3 Operations Principles

OBSERVATIONS - ROLES AND RESPONSIBILITIES

The Russians are responsible for the prelaunch, launch and docking of Soyuz TM 21 to the Mir Station. They also are responsible for the preparations and execution necessary for the safety of the crew throughout these phases.

The NASA center for operations and medical consultation will be the Science Management Area (SMA) in Building 35 at JSC. NASA technical personnel also will be located at the Baikonur launch side and in MCC-M.

OBSERVATIONS - MISSION MANAGEMENT, COMMUNICATIONS, AND METHODS

The prelaunch and launch phases are controlled in accordance with the standard Russian approach for Soyuz launches. The rendezvous trajectory profile of the Soyuz with the Mir Station follows a path of phasing and intercept maneuvers similar to the NASA profile. The targeting for the maneuvers is computed in MCC-M and uplinked to the Soyuz. The rendezvous is planned so that maneuvers and braking are during Acquisition of Signal (AOS) which allows MCC-M to monitor the Soyuz directly. Station keeping and docking are nominally performed by the automatic control system, although the Commander

²⁰

Janes Space Book, Tenth Edition (1994 - 1995), p. 28.

of the Mir Station can take over and complete or abort the docking manually.

Operations and coordination between the two sides will be conducted between MCC-M and the SMA at JSC.

NASA will provide technical personnel in MCC-M, primarily with the role of aiding in mutual understanding. NASA also will provide medical personnel in MCC-M and medical personnel at Baikonur.

OPERATIONS - NASA MEDICAL OPERATIONS

Preflight Medical Facilities and Access to Crew

The NASA flight surgeons office space is adequate. The pharmacy is well stocked and organized. Emergency packs have been assembled and are quite adequate for emergency medical assistance. The two NASA flight surgeons at Star City are held in the highest regard by Russians and Americans alike. They are professional and competent physicians who are doing an excellent job. There is no reservation about their preparedness to provide any level of emergency care.

Medical Facilities and Personnel at Baikonur

NASA is not staffing independent medical facilities at Baikonur.

Operational Preflight Medical Protocol

No preflight medication or water restriction regime is scheduled. A program of controlled access is utilized analogous to NASA's Health Stabilization Program. A brief physical examination is given five days prior to launch which includes finger stick blood work, electrocardiogram, and urinalysis. NASA flight surgeons will be involved with all phases of this protocol.

4.1.4 Rendezvous and Docking

OBSERVATIONS

Successful rendezvous and docking are critical to mission success. Failed automatic docking attempts in September 1994 of Progress M-24 and October 1994 of Soyuz TM-20 highlighted the dependence of long duration space missions on logistics and crew exchange as well

as the value of having manual and remote, teleoperated modes for backup. In response to questions regarding the causes and corrections to the automatic docking system anomalies, Review Team members were told in January that an algorithm (i.e., software) change had been made to accommodate a center of gravity location (moments of inertia) outside the original defined limits. During the February site visits, the Review Team members were informed that two additional high-gain antennas were added to the "Kurs" system to correct problems in roll.

Additional testing of the automatic docking system in November 1994 and January 1995 as well as the successful automatic docking of Progress M-26 on February 17, 1995, increased the Review Team's confidence in the automatic docking mode for the Soyuz TM-21 rendezvous and docking. Additionally, the Soyuz TM-21 crew are trained in manual docking for the Soyuz as well as remote, teleoperated docking from the Mir Station for the Progress. Teleoperated docking of Progress was demonstrated in September 1994 on Progress M-24. Similar backup capability has been incorporated into the Spektr and Priroda modules.

4.2 Mir 18 Main Expedition

4.2.1 Mir Station

OBSERVATIONS

Like the Soyuz booster and Soyuz spacecraft, the Mir Station is the product of decades of evolution. The first Soviet space station, Salyut 1, was launched on April 19, 1971. Salyut 1 - 5 (April 1971 - August 1977) comprised the first generation, Salyut 6 and 7 (September 1977 - June 1986) the second, and the Mir Station (February 1986 - present) is considered the first station of the third generation. The dividing line between generations is not appearance as much as it is "capability and robustness"²¹.

²¹ A Russian Space Station: The Mir Complex, JSC Mission Operations Directorate, February 10, 1994, p. 1-1.

The Mir base block was launched on February 19, 1986. Between March 1987 and June 1990, three additional modules were added to the Mir base block. These modules are as follows:

- Kvant 1 (launched March 31, 1987): Astrophysics module
- Kvant 2 (launched November 26, 1989): Mir extension module and EVA airlock
- Krystal (launched May 31, 1990): Materials processing laboratory with four furnaces and androgenous docking port (to be used for Shuttle-Mir docking)

During its first nine years, the Mir Station has been manned by a total of 51 crewmembers including 11 foreign cosmonauts.

During the course of Phase 1, two additional modules will be added to the Mir Station. These modules and their scheduled launch dates are as follows:

- Spektr (scheduled launch date - May 10, 1995): Adds four additional solar arrays to Mir Station; remote sensing and equipment for a wide variety of U.S. flight experiments -- 755 kg. of U.S. science hardware
- Priroda (scheduled launch date - November 10, 1995): Primarily Earth sensing and microgravity; over 1000 kg. of U.S. science hardware

4.2.2 Systems

OBSERVATIONS - CURRENT MIR STATION SYSTEM REDUNDANCY

A formal safety hazard analysis has been conducted by the U.S. and Russia for the approach, docking, and docked phase of the STS-71 mission. Included in that analysis was Mir Station system redundancy which confirmed that all Mir Station life critical systems are triple redundant.

RSC Energia reported that all systems are at full redundancy and that redundancy can be restored when necessary with spare parts either already on the Mir Station or in stock on the ground. Additionally, a report on current Mir Station safety and reliability is provided quarterly to NASA. Procedures are in place for hardware replacement either as part of the preventative maintenance program or in response to failures. Each year, TsNIIMASH recertifies each system for the following year. This is facilitated by the fact that RSC Energia has a

full-scale integrated test version of the Mir Station, complete with flight length cables, in its plant. The JSC Mir Extension Assessment Team is currently assessing hardware requirements to support all Phase 1 activity.

The most complex systems on board are the computer system and the attitude control system including gyroscopes. High moisture content on previous Salyut Space Stations (particularly Salyut 6) led to development of procedures to ensure thermal and humidity control for Mir Station. These are carefully monitored. A recent analysis of cables returned from orbit show no evidence of corrosion.

Hardware on the outside of the Mir Station is addressed differently. Numerous EVAs have been used to affect repairs and maintenance. Although certain systems cannot be repaired or replaced (e.g., propulsion system, thermal control system, etc.), these have been built with a significant safety margin. For hardware which cannot be replaced, additional redundancy is used in place of repair. Examples include:

- Manifold in the propulsion system -- increased redundancy using a second system which has already been tested.
- Pipelines -- double redundancy.
- Failure of Thermal Control System -- fallback procedures are in place in the event that both systems fail; heaters are an effective technique to counter the situation.

On October 11, 1994 the Mir Station suffered a nearly total loss of electrical power. Several factors contributed to this situation. In summary, the power loss anomaly appears to have been caused by a combination of an aging system with small margins, an abnormally high power demand caused by a large number of crewmembers on-board, a reliance on the ground for systems management coupled with a lack of communications coverage, and several procedural errors. This incident emphasized the need to maintain adequate communications.

In May 1995, Spektr will add four solar panels to Mir Station's current complement plus additional batteries. As part of this process, two arrays on Kristall must be retracted, moved to the Kvant module, and re-extended. If the arrays cannot be retracted and re-extended they will be discarded. Kristall solar arrays have redundant electrically driven motors for extension and retraction, but no additional manual mechanical mode is provided. Only one array is necessary to carry

out a reduced science program. Power loss caused by failures in the redeployment of both solar arrays and the inability of Spektr to dock will force reduction of Mir Station operations to orbit maintenance. The Environmental Control and Life Support System (ECLSS) loads can not be supported and temporary departure of the crew could become necessary.

OBSERVATIONS - SYSTEM MARGINS

System operating performance margins are established where appropriate (e.g., propellant quantity redlines, power consumption, battery state of charge). Activities that exceed the nominal planned levels can be authorized by the flight control team as long as the pre-mission margins are not compromised. To intentionally violate these margins, permission must be obtained from the spacecraft designers.

OBSERVATIONS - ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEMS (ECLSS)

Atmosphere

The spacecraft environment is believed to be safe although occasional spikes of contaminants above limits have been observed. Cosmonaut debriefings with previously flown Mir Station cosmonauts reveal no subjective problems with the atmosphere. Samplings of the Mir Station atmosphere are being collected and will be analyzed after the return of the Mir 17 Main Expedition crew on March 22, 1995.

Potable H₂O

The potable water supply has been acceptable and drinking from it has not resulted in significant medical sequelae. A detailed evaluation of the environmental control system can be found in the "Technical Assessment of Mir 1 Life Support Hardware for the International Space Stations" by Kenneth L. Mitchell, et al.

Environment

Real-time, on-board radiation monitoring is available although the exact equipment was not discussed. The expected absorbed dose is calculated between 2.7 and 4.5 REM. The acoustic environment ranges from 60-62 db in the rest areas and 67-72 db in the work spaces. These are within acceptable limits for a 90-day mission.

4.2.3 Experiments

OBSERVATIONS - SCHEDULED EXPERIMENTS AND EXPECTATIONS

A complement of scientific experiments were proposed for the Mir 18 Main Expedition to afford an early opportunity to conduct long duration (three months) life sciences investigations and microgravity environment characterization of the Mir Station. Several reviews of experiments were performed as a result of peer scientific review and safety concerns. Final baselining of the experiments did not occur until Feb 8, 1995, or five weeks before launch. The Review Team was advised that of 34 planned experiments, only 28 are now scheduled to be flown.

Preparation of the on-board experimental hardware fell behind schedule due to a combination of circumstances. Delays in shipment to Russia and delays in Russian customs resulted in late flight and training hardware deliveries. In addition, the experiment procedures delivered for translation from English to Russian were produced in formats inappropriate for flight use and the translated procedures were late in delivery. The late delivery of the equipment and procedures resulted in a compressed training schedule which has placed the U.S. astronaut at risk of not being able to satisfactorily conduct some experiments. This is compounded by the lack of configuration control for equipment stored on-board (see Stowage Inventory below).

In addition to the reduction in the number of experiments, it must be noted that the aging Mir Station requires considerable on-orbit repair, thereby potentially reducing crew time available for science. The assistance of a cosmonaut is necessary to the success of numerous flight experiments which are considered time critical. Although the cosmonauts have agreed to assist in these experiments, Mir Station maintenance priorities may preclude their availability. If the assistance of a cosmonaut is not available, the experiments which require that assistance should be rescheduled.

Another factor which needs to be considered is the scheduled late arrival of life science experimental hardware contained within the Spektr module. The majority of the experimental hardware is to be launched on Spektr which will not dock until late in the Mir 18 Main Expedition timeline. When one considers the time from launch to docking (7-10 days), Spektr activation time (three weeks), and pre-

deorbit time requirements for the U.S. astronaut, the useful time for many of the inflight life science experiments on this first mission will be minimal.

It seems inevitable that the combination of these factors will result in a minimal inflight science yield for the Mir 18 Main Expedition. As a result, the emphasis on this first joint mission must be on the acquisition of operational experience with the Soyuz, Mir Station, the Mir Station environment, MCC-M and crew activities.

RECOMMENDATIONS

- 4.2.3.1 NASA must tailor expectations for science during the Mir 18 Main Expedition due to the late arrival of experiment hardware and flight procedures. Emphasis in the science area should focus solely on astronaut Thagard's efforts to characterize the Mir Station environment and provide valuable lessons on how to best achieve U.S. scientific goals aboard the Mir Station. The successful completion of specific experiments should be viewed within this context rather than as a separate measure of success.**
- 4.2.3.2 If the assistance of a cosmonaut is not available during Mir 18 Main Expedition to conduct time critical experiments, the experiments which require that assistance should be rescheduled.**
- 4.2.3.3 It is imperative that flight and training hardware for U.S. experiments as well as flight procedures be available in Russia in accordance with a jointly agreed upon schedule. In the event that the necessary items are not available within that schedule, the experiment should be postponed or cancelled.**

OBSERVATIONS - STOWAGE INVENTORY

Debriefings with previous Mir Station crewmembers have highlighted the lack of a prearranged set of stowage locations for experiment equipment. Additionally, no inventory list is maintained. In combination, these issues make performing time critical science experiments difficult. Review Team members were advised that the team of experimenters will attempt to help the crew in maintaining a stowage location inventory for science experiments.

OBSERVATIONS - INVASIVE PROCEDURES

Only two experiments are invasive. The first involves a peripheral venous catheter used to measure central venous pressure. The U.S. astronaut and one Russian cosmonaut are trained in this procedure. The second involves an infusion of calcium chloride to be performed on Atlantis prior to the STS-71 deorbit.

RECOMMENDATION

- 4.2.3.4 The remaining invasive protocol for Mir 18 Main Expedition crewmembers, the calcium-chloride infusion scheduled to occur aboard the Shuttle during STS-71, should be carefully reviewed by medical operations before implementation.**

OBSERVATIONS - INSTITUTIONAL AUTOMATED DATA PROCESSING AND TELECOMMUNICATIONS (ADP/T)

Although the initial requirements definition began in 1993, the NASA institutional ADP/T infrastructure (e.g., telephones, facsimile machines, voice teleconferencing systems, computer equipment, etc.) in Russia is still rudimentary. Implementation plans have been developed; however, actual installation has been delayed for a variety of reasons. This schedule slippage has had a significant impact on mission preparation as well as other aspects of day-to-day operations.

RECOMMENDATION

- 4.2.3.5 Implementation of NASA institutional automated data processing and telecommunications (ADP/T) capabilities in Russia must be given a high priority.**

4.2.4 Mir Station Assured Crew Return Vehicle (ACRV) - Soyuz

Whenever crews are aboard the Mir Station, a Soyuz spacecraft is docked and ready for immediate crew ingress. In the event of a cabin loss of pressure or any life threatening condition on-board the Mir Station, the crew can retreat to the docked Soyuz, depart the station, and initiate the return to earth sequence. The Soyuz-TM spacecraft has a docked-to-station endurance of at least 180 days. A visiting or replacement crew will dock at an alternate docking port in a fresh Soyuz. The returning crew will use the aging spacecraft, leaving the fresh one for the resident crew. A variation of this procedure had an

unmanned Soyuz sent to the station to replace the resident crew's aging spacecraft. This was done only once when Soyuz 34 replaced Soyuz 32.

4.2.5 Operations Principles

OBSERVATIONS - ROLES AND RESPONSIBILITIES

The Russians are responsible for the conduct of the Mir 18 Main Expedition. They are also responsible for the safety of the crew aboard the Mir Station throughout this phase.

The NASA center for operations and medical consultation will be the Science Management Area (SMA) in Building 35 at JSC. NASA technical personnel will be located at MCC-M.

OBSERVATIONS - MISSION MANAGEMENT, COMMUNICATIONS, AND METHODS

The long duration aspect of the mission has a pronounced effect on the approach to planning crew and MCC-M activities. There is no pressure to detail activities for the entire mission. Four MCC-M teams rotate shifts of 24 hours duration. Their role while on duty is to monitor and support during the crew activity period, and during the crew rest period to plan the activities for their next shift (four days hence). The spacecraft systems expert support is available for consultation during the crew active periods and could be summoned at other times if necessary.

The flight plan uplinked to the crew at the beginning of their work day is a general listing of planned activities for the next duty period of the current MCC-M team. The crew is expected to be knowledgeable of the procedures and detail sequence of events or to get them from on-board documentation. The MCC-M schedules routine maintenance events for the crew to perform. Repairs and replacement of failed or depleted components is performed at crew initiative. Crew rehearsals of emergency procedures are conducted periodically.

The crew work day is maintained on Moscow time. Because of orbital precession, crew activities often occur outside of coverage by the Russian ground stations for several hours at a time. This places a high importance on the use of the two Luch communications relay satellites for contingency operations. Our understanding is that these

satellites are not fully utilized and only are scheduled for selected periods of activities. Statements made to the Review Team indicate that these satellites can be scheduled with a one-day lead time required. In a highly critical emergency, satellite communications can be obtained in approximately 6 hours.

Operations coordination between the two sites will be conducted between MCC-M and the SMA at JSC. It was stated that there will be a daily scheduled teleconference to assess the progress and status of the mission. NASA will provide technical personnel at MCC-M primarily with the role of aiding in mutual understanding.

OBSERVATIONS - MEDICAL OPERATIONS

Medical Communications

Weekly medical communications are scheduled, and the confidentiality of these conversations will be observed. Both audio and visual modes are available. As stated above, emergency communications can be established through satellite links; however, required lead time can be up to six hours.

Physiological Countermeasures

The obligatory countermeasure protocols include the use of treadmills, veloergometer (bicycle ergometer), expanders (bungee exercise cords), THK-Y1 and Pinguin suit for skeletal loading, Karkas suit, (anti-G suit) and CHIBIS (Lower Body Negative Pressure) suit. These are well documented and the Russians have extensive experience in their implementation. Electrostimulator and Braslet devices are optional.

Emergency Medical Procedures and Medical Kits

All Russian crewman are trained in basic medical emergency procedures and in the use of the on-board medical kits. Both Russian and U.S. medical kits will be aboard Mir Station. The U.S. medical kits were delivered to Mir Station via Progress M-26 on February 17, 1995.

4.3 STS-71

Prior to this report, the Task Force had already concentrated considerable effort in reviewing preparations for STS-71 (see Task Force reports dated

June 6, 1994, July 29, 1994, and November 2, 1994). The information in the following sections is intended as an update to the material contained in the previous reports.

4.3.1 Rendezvous and Docking

Preparations for rendezvous and docking of STS-71 to Mir Station are considered adequate based on findings which include the following:

OBSERVATIONS - RCS PLUME AND DOCKING LOADS ANALYSIS

Extensive work has been done in analyzing both the RCS plume and docking loads for the Shuttle-Mir docking scheduled to occur on STS-71. Plume impingement data from the STS-64 Shuttle Plume Impingement Flight Experiment compared favorably with the JSC plume models. This, in addition to data obtained from a 250 run matrix in the Shuttle Engineering Simulator consisting of approach and docking runs, helped provide confidence to proceed with an approach to within 10 meters (32.5 feet) of Mir Station during STS-63 on February 17, 1995. Preliminary observations from the V-bar approach of Discovery to Mir Station revealed no apparent disturbance of the Mir Station during rendezvous, close approach to 10 meters, or 400 foot fly-around when utilizing the low-Z mode of the Shuttle Digital Autopilot. Mir Station attitude maintenance during all phases was within one arc-minute (0.017 degree) using its gyrodyne stabilization system. R-bar approaches, which are planned for all subsequent flights, normally require less RCS braking and should, therefore, further reduce plume loads and contamination on the Mir Station. Based upon the combination of analyses performed to date and validated by flight tests on STS-64, STS-66, and STS-63, the Task Force has no remaining concerns regarding plume loads on the Mir Station solar arrays for the STS-71 rendezvous, proximity operations, and docking maneuvers.

OBSERVATIONS - FLEXIBILITY OF APPROACH PROFILES

Although STS-63 flew a V-bar approach, an R-bar approach is planned for STS-71 and subsequent Phase 1 docking missions. In fact, because of an anticipated unique Mir Station solar panel configuration for this flight, STS-71 will fly the approach to docking in a 90 degree nose out-of-plane attitude to minimize thruster plume impingement. Although there are geometry and technique differences, the difference in piloting task levels and associated training is minimal.

OBSERVATIONS - JOINT CONTINGENCY PLANNING AND RESPONSE

After orbit insertion of STS-63, two orbiter primary RCS thruster leaks were discovered. The leak rate was sufficient to create a concern of contamination to the entry attitude horizon scanner on the Soyuz return vehicle. Attempts to stop the leaks were unsuccessful, so an alternate procedure of closing and isolating the affected manifolds was proposed. This stopped the thruster leaks, but also removed the redundancy of the RCS system during the approach and proximity operations. After careful consideration, it was determined that this procedure was appropriate and, if necessary, the affected manifolds could be reactivated. However, the concurrence of the appropriate Russian management, based on trust and confidence in NASA's systems knowledge and decision making process, was the key to accomplishment of the important mission objective of closing to approximately ten meters. This demonstration provides a strong foundation for success of upcoming docking missions.

OBSERVATIONS - COMMUNICATIONS

In addition to the normal air to ground communications for both Orbiter and Mir Station from their respective control centers, during STS-63 Orbiter to Mir Station communications was conducted via VHF radio using a window mounted antenna. Range performance exceeded mission requirements. Good communications was established at a range in excess of 90 nautical miles. A consensus observation of Review Team members at the MCC-H was that there appeared to be an excess of non-essential communication traffic during the close approach and proximity operations.

OBSERVATIONS - ORBITER ATTITUDE AND PROFILE CONTROL

Precise attitude, range and range rate control as demonstrated by the crew of STS-63 appeared to verify the simulator modeling and training, and analysis by JSC Engineering and Mission Operations Directorates. At the closest approach range of 36 feet, attitude errors all three axes appeared to be within the desired 2 degree limit. However, a two degree angular fly-out maneuver was performed for task and procedure demonstration.

OBSERVATIONS - ALIGNMENT SENSOR

On STS-63, a color television camera (CTVC) which will be the primary visual sensor for displacement and angular alignment during docking, was mounted in the Spacehab and evaluated for Mir Station target visibility and closed circuit television monitor resolution during STS-71 docking. Initial crew comments indicate target visibility and resolution is usable for alignment and fly-out inside a range of 36 feet using the unzoomed lens of the CTCV.

4.3.2 Mated Operations

OBSERVATIONS

Analysis to date performed by JSC Engineering indicates that Shuttle using either primary or vernier RCS, or Mir Station using gyrodynes or reaction control system jets is capable of controlling attitude of the combined stack. On STS-71 during the 5 days of mated operations, attitude control of the mated stack will be accomplished 2 1/2 days by the Orbiter Flight Control System (FCS) and 2 1/2 days by the Mir Station Attitude Control System (ACS).

4.3.3 Separation

OBSERVATIONS - NORMAL (ODS) OPERATION

Normal separation of the Shuttle from the Mir Station is initiated by retraction of the active hooks in the Androgenous Peripheral Docking System (ODS) via electromechanical actuators. Although anomalies were experienced during qualification testing, appropriate engineering design changes were incorporated and thoroughly tested. Design engineers and managers from both sides are completely satisfied that all qualification testing anomalies have been resolved.

OBSERVATIONS - CONTINGENCY (PYROTECHNIC BOLTS) SEPARATION

In the event the structural active hooks are not retracted with the dual redundant electrical motors, a contingency separation capability exists by firing pyrotechnic bolts in the hooks. Pyrotechnic certification for reliability has proceeded without incident and the Review Team was informed at RSC Energia that testing is scheduled to be completed by the first week in April.

OBSERVATIONS - EVA DEMATE CONTINGENCY

In the event of a failure of the orbiter docking system motor driven latches, and then a subsequent failure in the pyrotechnic bolt release system, an EVA will be used as the third means of separation of the Shuttle from the Mir Station. EVA tools and procedures have been developed and high-fidelity Weightless Environment Training Facility (WETF) training began in late November 1994. Although the failure scenarios requiring this procedure are extremely remote, there is a high level of confidence that this EVA separation can be satisfactorily accomplished.

4.3.4 Operations Principles

OBSERVATIONS - ROLES AND RESPONSIBILITIES

The Russians are responsible for the continued conduct of the Mir 18 Main Expedition and the safety of the crew aboard the Mir Station.

NASA is responsible for the planning, training, and conduct of the Shuttle phase of the mission - STS-71. NASA also is responsible for the safety of the crew aboard the Shuttle throughout all of the Shuttle phases of the mission.

OBSERVATIONS - MISSION MANAGEMENT, COMMUNICATIONS, AND METHODS

The STS-71 mission is a joint mission with both MCC-H and MCC-M having active roles and responsibilities per their normal mode of operation. The joint activities requiring coordination and cooperative actions are planned and controlled in a manner very similar to those of Apollo-Soyuz Test Project (ASTP). Detailed, specific mission rules for the joint phase of operations are developed by the operations organizations, and jointly approved by the technical director. Details of the trajectory planning for rendezvous, station keeping, and docking are prepared and jointly analyzed by both sides. The rules define trajectory dispersion limits and systems configuration and performance constraints for the joint phase of the mission. Also included are rules regarding crew procedures for anomaly responses. Training and simulations are conducted to verify the plans and applicability of the mission rules.

The Shuttle is the active vehicle throughout the rendezvous and docking. The Mir Station remains in a prescribed attitude and makes no translational maneuvers for the 48 hours preceding the Shuttle launch through the completion of rendezvous. A joint "Go/No Go" decision is required for initiating docking. The recent STS-63 flight in February 1995 with the close approach to the Mir Station by the Shuttle gives considerable confidence in this joint phase of the mission.

Operations coordination between the two sides will be conducted between the Mir Station and Shuttle crews and between MCC-M and MCC-H.

NASA will provide technical personnel in MCC-M, primarily in the role of support and clarification. Russia will provide technical personnel in at MCC-H in the same role.

NASA also will maintain medical personnel at MCC-M and Russia will have medical personnel MCC-H to coordinate in inflight and post-flight medical matters relevant to the returning cosmonauts.

OBSERVATIONS - TRAINING

Standard STS mission training for a rendezvous mission has been augmented with Russian language lessons and joint U.S.-Russian integrated training simulations. Previous experience on STS-63 has shown this to be representative of the Shuttle-Mir mission environment. Both the flight crew and the mission control centers are well qualified and prepared to conduct the STS-71 mission.

5 APPENDICES

**NASA Advisory Council
Task Force on the Shuttle-Mir
Rendezvous and Docking Missions
Russian Review Team**

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DEC 6 1994

Lieutenant General Thomas P. Stafford, USAF (Ret.)
Stafford, Burke and Hecker, Inc.
1006 Cameron Street
Alexandria, VA 22314

Dear Gen. Stafford:

I am requesting that, in your role as Chair of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions, you lead a team composed of several Task Force members and technical advisors to Russia to review preparations and readiness for the upcoming international Space Station Phase 1 missions. Given the outstanding work the Task Force has produced to date, as well as your personal rapport with members of the Russian Space Program, I believe that a team led by you will provide NASA with an additional level of confidence.

I would like to receive your report prior to March 1, 1995. Please accept my gratitude for the valuable work you and your team have already done and for assisting NASA further in this critical effort. If I can be of any assistance, please do not hesitate to contact me.

Sincerely,

A handwritten signature in black ink, appearing to read "Daniel S. Goldin". The signature is fluid and cursive, with a large, stylized "D" and "G".

Daniel S. Goldin
Administrator

Preliminary Working Group

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Operations Team

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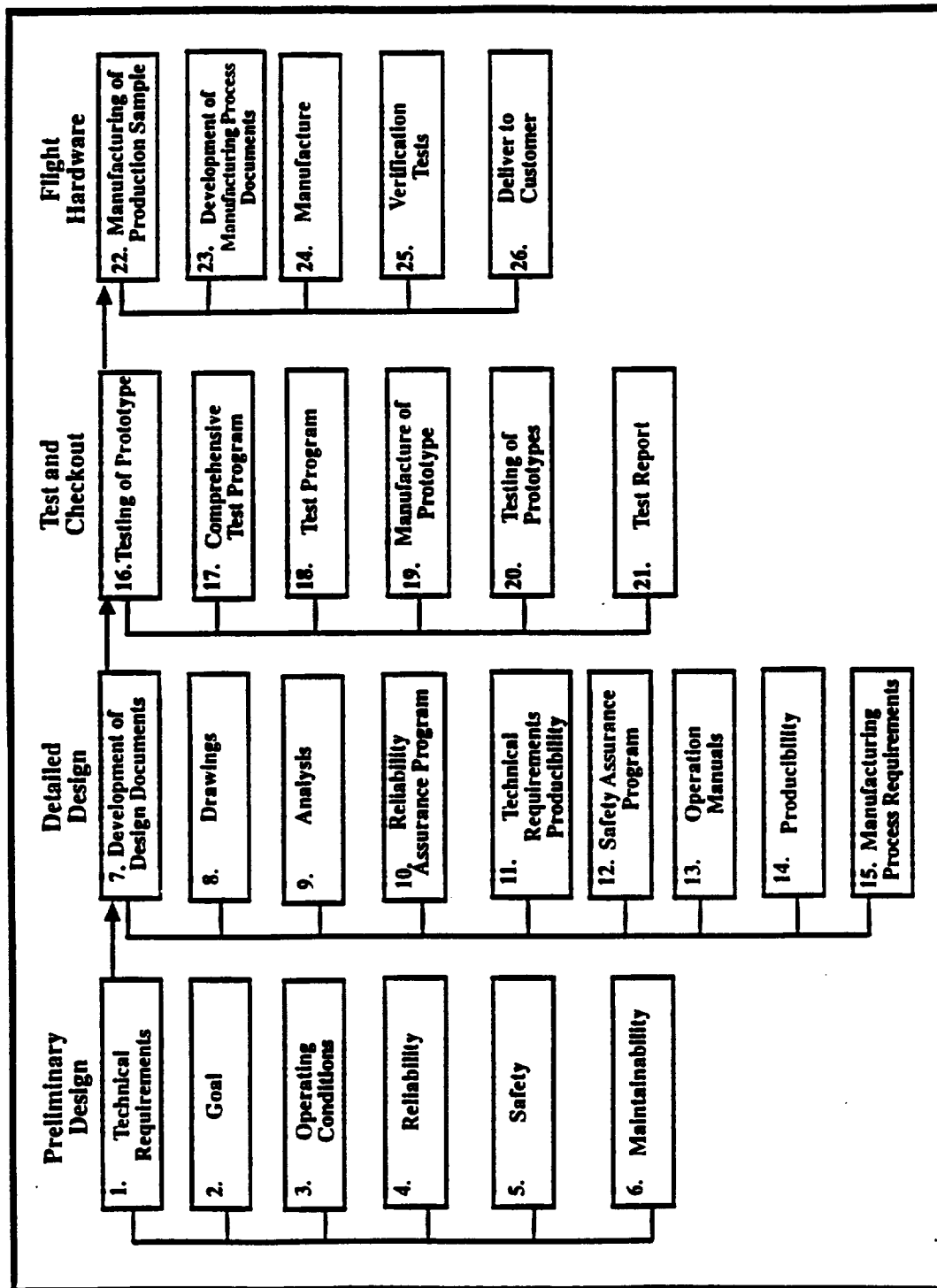
Dr. Bobby Ray Alford

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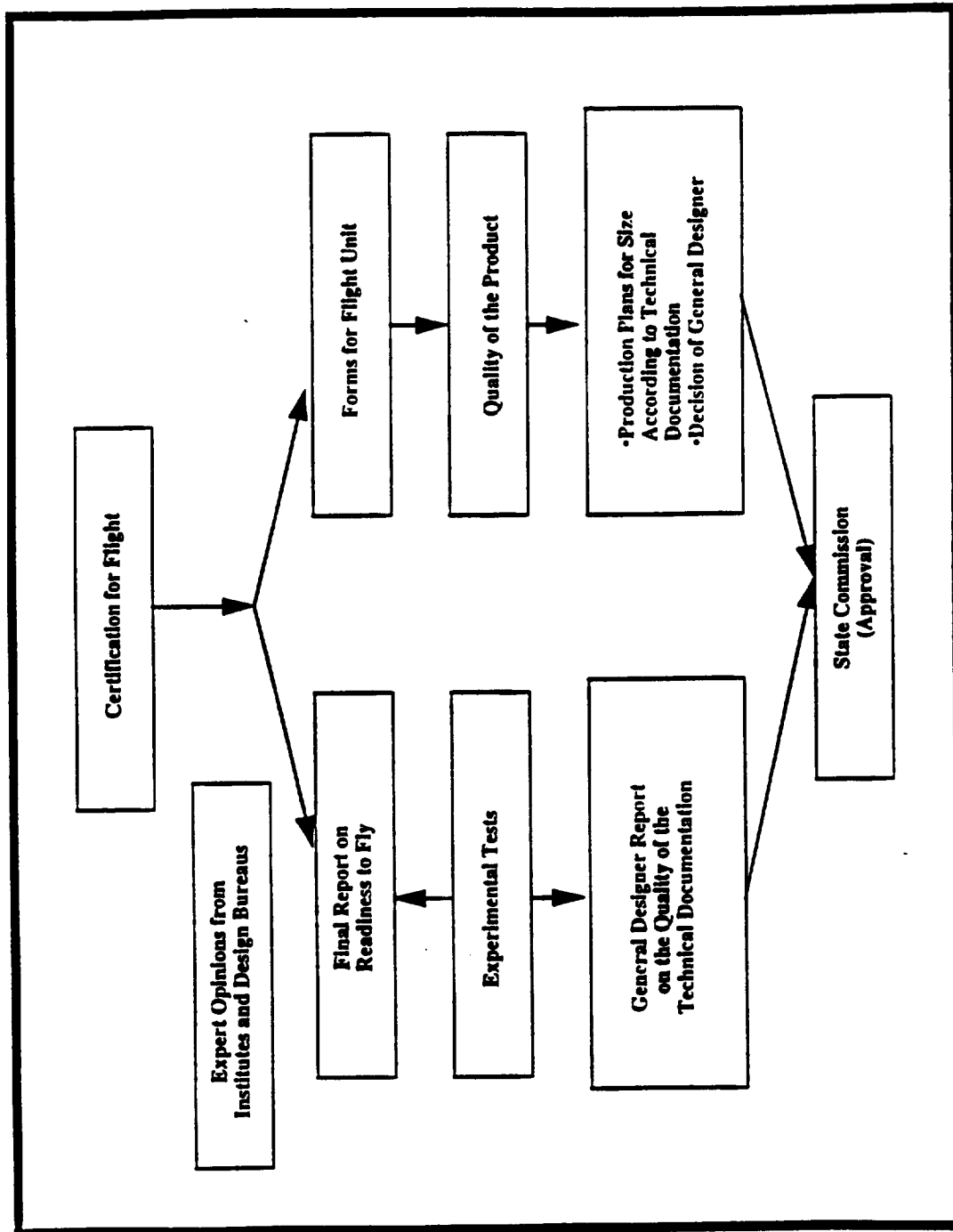
Dr. Craig Fischer*

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* Participated in Preliminary Working Group site visits in Russia (January 1995)



Russian Engineering Design and Manufacturing Process



Flight Certification Process

ACRONYM LIST

AAS	Aeromedical Flight Squadron
ACLS	Advanced Cardiac Life Support
ACRV	Assured Crew Return Vehicle
ACS	Attitude Control System
ADP/T	Automated Data Processing and Telecommunications
AES	Aeromedical Evacuation Squadron
AIT	Analysis Integration Team
AOS	Acquisition of Signal
APDS	Androgenous Peripheral Docking System
AR&D	Automated Rendezvous and Docking
ASTP	Apollo-Soyuz Test Project
ATLS	Advanced Trauma Life Support
CIS	Commonwealth of Independent States
CG	Center of Gravity
CoFR	Certificate of Flight Readiness
CMEV	Command Message Encoder Verifier
CR	Change Request
CTVC	Color TeleVision Camera
DAP	Digital Autopilot
db	Decibel
DM	Docking Module
DTO	Development Test Objective
ECLSS	Environmental Control and Life Support System
ET	External Tank
EVA	Extra-Vehicular Activity
FEL	First Element Launch
GCTC	Gagarin Cosmonaut Training Center
HHL	Hand Held Lidar
HST	Hubble Space Telescope
IBMP	Institute for Biomedical Problems
IMU	Inertial Measurement Unit
IPT	Integrated Product Team
ISSA	International Space Station Alpha
IV&V	Independent Validation and Verification
LBNP	Lower Body Negative Pressure
Lidar	(L)ight (D)etection (a)nd (R)anging
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
LES	Launch Escape System
LOS	Loss of Signal

ACRONYM LIST (CONTD)

MCC-H	Mission Control Center - Houston
MCC-M	Mission Control Center - Moscow
MOA	Memorandum of Agreement
MOD	Mission Operations Directorate
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NIICHIMMASH	Institute of Chemical Machine Building
NIITP	Scientific Institute of Thermal Processes
NSTS	National Space Transportation System
OAST-Flyer	Office of Aeronautics and Space Technology - Flyer
ODS	Orbiter Docking System
OLMSA	Office of Life and Microgravity Sciences and Applications
OMDP	Orbiter Maintenance Down Period
OSMA	Office of Safety and Mission Assurance
OV	Orbiting Vehicle
OV-103	<i>Discovery</i>
OV-104	<i>Atlantis</i>
PCMMU	Pulse Code Master Modulation Unit
PFR	Portable Foot Restraint
PGSC	Payload and General Support Computer
PIO	Public Information Officer
PLB	Payload Bay
PRCB	Program Review Control Board
PRCS	Primary Reaction Control System
Prox Ops	Proximity Operations
PSC	Payload Steering Committee
R-bar	Radius Vector
RCS	Reaction Control System
REM	Roentgen Equivalent in Man
RMS	Remote Manipulator System
RN/EMT	Registered Nurse/Emergency Medical Technician
ROCC	Range Operations Control Center
RPOP	Rendezvous and Proximity Operations Program
RSA	Russian Space Agency
RSC-Energia	Rocket Space Corporation - Energia
RTLS	Return to Launch Site
TsNIIMASH	Central Scientific Research Institute for Machine Building
SAREX	Shuttle Amateur Radio Experiment
SES	Shuttle Engineering Simulator
SLSD	Space and Life Sciences Division (JSC)
SMA	Science Management Area

ACRONYM LIST (CONT'D)

SPARTAN	Shuttle Pointed Autonomous Research Tool for Astronomy
SPAS	Shuttle Pallet Satellite
SPIFEX	Shuttle Plume Impingement Flight Experiment
SRB	Solid Rocket Booster
SSP	Space Shuttle Program
SPO	Shuttle Program Office
SSPO	Space Station Program Office
TCS	Trajectory Control Sensor
TRAD	Tools for Rendezvous and Docking
V-bar	Velocity Vector
VHF	Very High Frequency
VRCS	Vernier Reaction Control System
WETF	Weightless Environment Training Facility
WG-0	Joint Management Working Group
WG-1	Joint Public Relations Working Group
WG-2	Joint Safety Assurance Working Group
WG-3	Joint Flight Operations and Systems Integration Working Group
WG-4	Joint Mission Science Working Group
WG-5	Joint Crew Training and Exchange Working Group
WG-6	Joint Mir Operations and Systems Integration Working Group
WG-7	Joint Extravehicular Activity Working Group
WG-8	Joint Medical Operations Working Group

